



NASA Ames Research Center Planning and Scheduling Group

David Smith, Group Lead
Jeremy Frank, Presenter



11/30/2004

ASR Group Introductions

Who We Are

- Staff

- David Smith (Group Lead)
- Andrew Bachmann
- Tania Bedrax Weiss
- Emmanuel Benazera
- Will Edgington
- Jeremy Frank
- Keith Golden
- Ari Jonsson
- Lina Khatib
- Elif Kurklu
- Conor McGann
- Nicolas Meuleau
- Paul Morris
- Robert Morris
- Sailesh Ramakrishnan
- Wanlin Pang

- Affiliates

- John Bresina (IRG)
- Illah Nourbakhsh (IRG)
- James Crawford (ARA Lead)
- Michael Freed (CAA)
- Nicola Muscettola (CAA)
- David Rijsman (CAA)
- Mark Drummond

- Students & Faculty

- Ronen Brafman (BGU)
- Michael Iatauro (WVC)
- Patrick Daley (De Anza)
- Mausam (UW)
- Matthew Boyce (UCSC)

Planning and Scheduling Overview

- Philosophy
 - Planning
 - Scheduling
- Technology
 - Planning for Uncertainty
 - Constraints and Optimization
 - Application Integration
- Activity



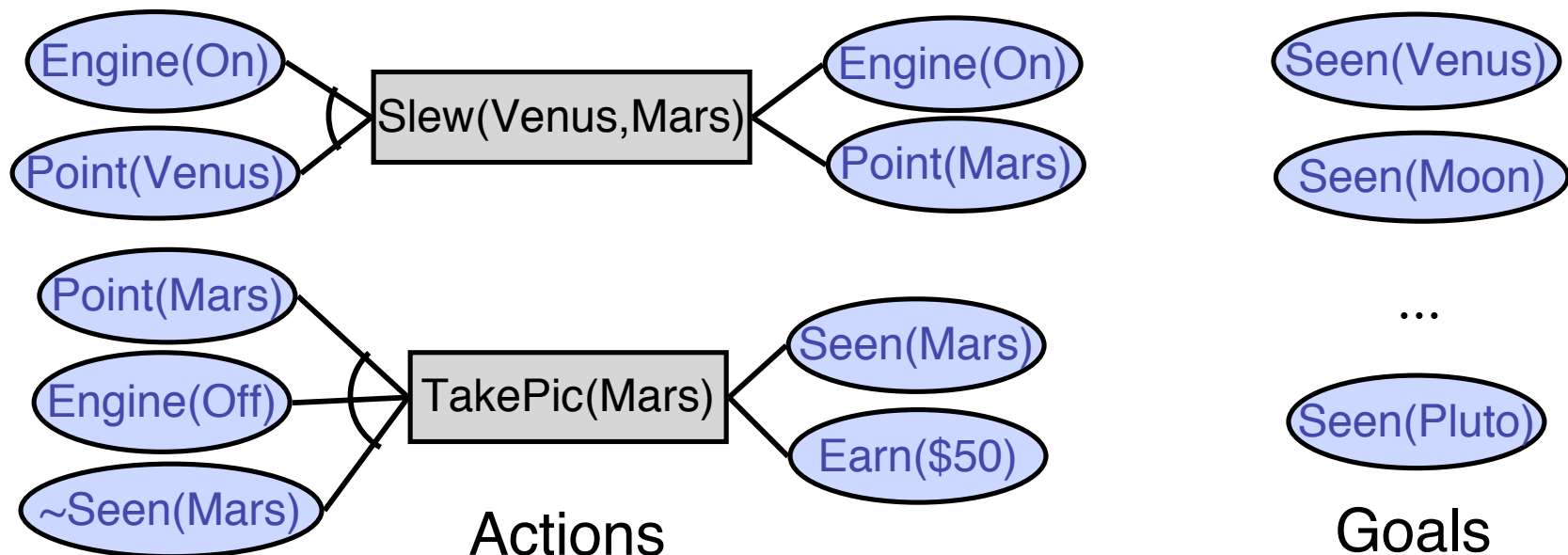


Planning and Scheduling

- Planning requires *choosing actions to satisfy goals*
 - ...leading to new action choices
- Scheduling requires *sequencing actions*
 - ... to satisfy constraints on legal sequences
- Planning need not have a scheduling component...
- Scheduling need not have a planning component...
- ...but many NASA problems combine aspects of both

What is Planning?

- Desired state(s) of the world (S)
 - Goals to achieve, e.g. Take picture of Mars
 - Could have value, i.e. picture of Mars worth \$50
 - Could be oversubscribed (more goals than can be accomplished)

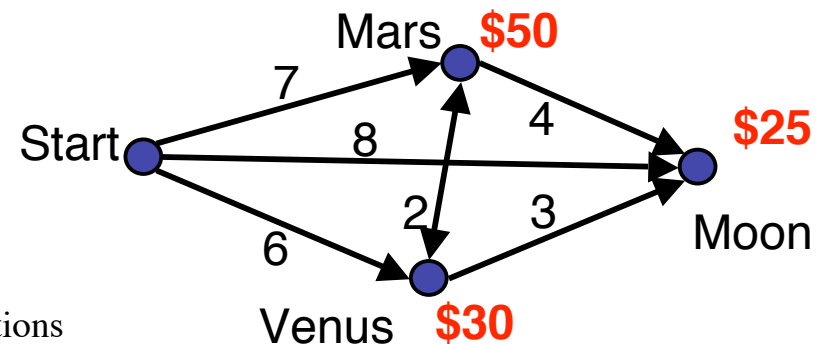
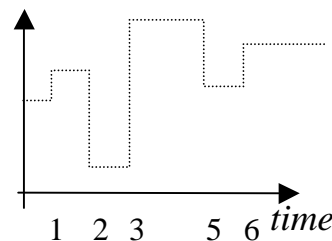
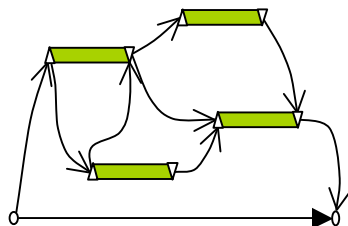


What is Planning?

- Current state of the world
 - Known facts, e.g. spacecraft orbiting Earth
- Activities and their outcomes
 - Turn engine on requires fuel flow (precondition)
 - Turn engine on results in movement (effects)
 - Turn engine on prevents take picture (mutex)
- Given current state and set of actions, can goals be achieved?
 - If so, what is best set of goals that can be achieved?

What is Scheduling?

- A set of tasks (e.g. take a picture, turn on engine)
- A set of constraints
 - Take picture of Mars between 5:00 and 5:30
 - Can't take picture while engine is on
- A set of preferred outcomes
 - Picture of Mars worth \$50, picture of Moon worth \$25
- What's the best schedule satisfying all constraints?



Features of Our Problems:

- Exogenous conditions & events with time constraints
- Over-subscription: too many activities
- Continuous uncertainty: activity duration, resource use
- Ramifications: complex consequences of actions
- Plan Revision: continuous requests for new plans
- External Reasoning aggravates 1-5

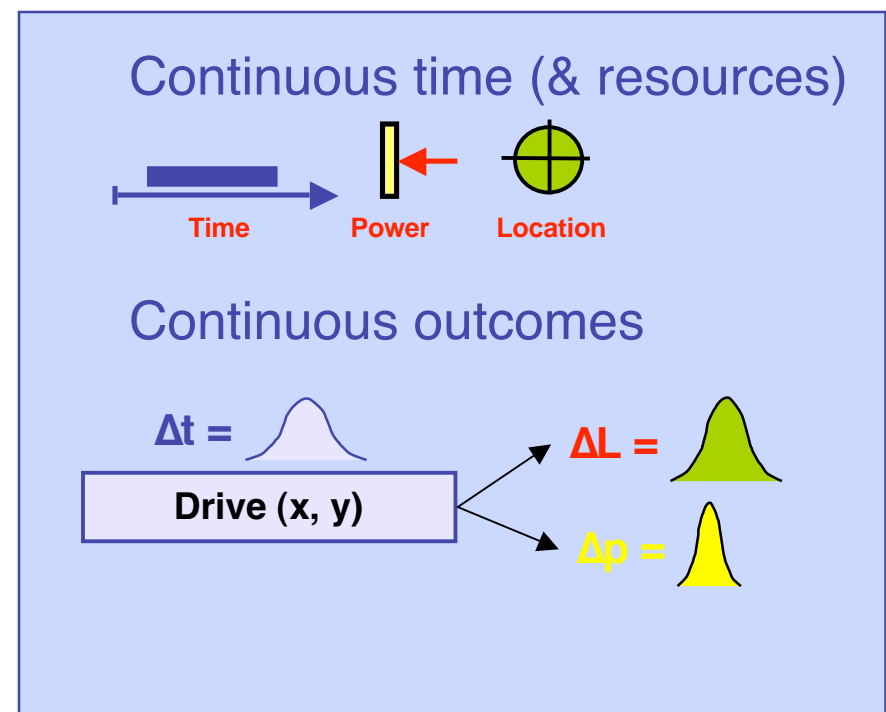
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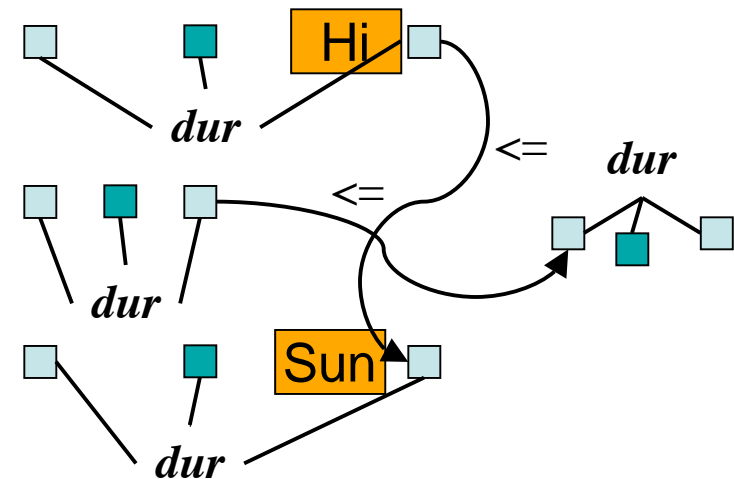
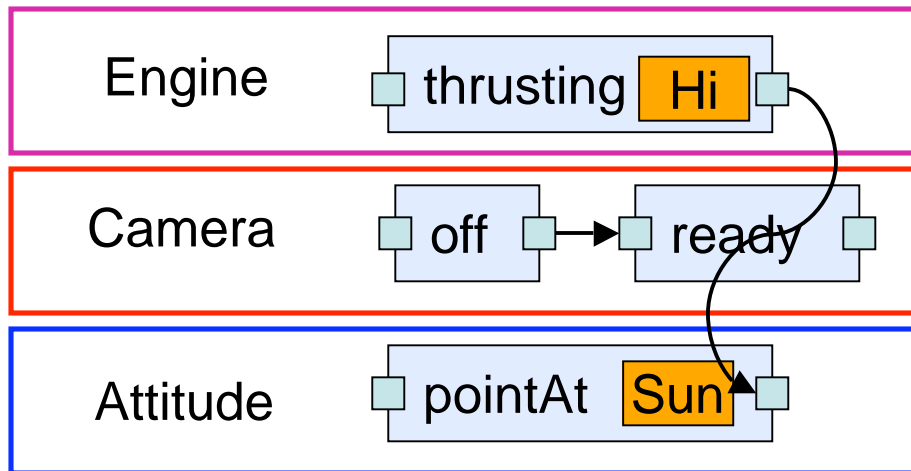
Planning for Uncertainty

- Plan for Uncertainty
 - Build Flexible plans
 - Build Contingent plans
- React to change
 - Replan on the fly
 - (Overlap w. CAA)



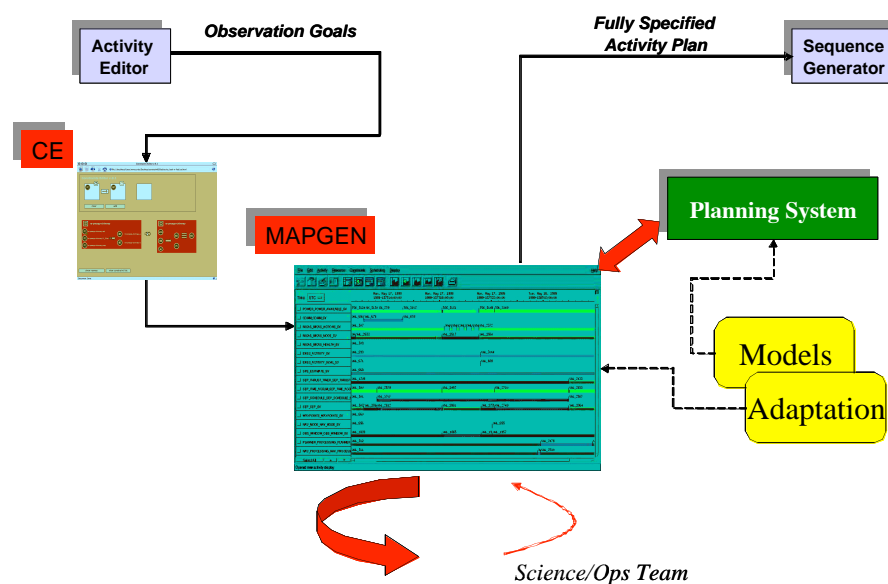
Constraints and Optimization

- Use Constraint Reasoning for planning
 - Fast, sound inference speeds up planning
 - Useful for describing rich class of problems
- Natural extensions to OR techniques
- Leverage existing research communities



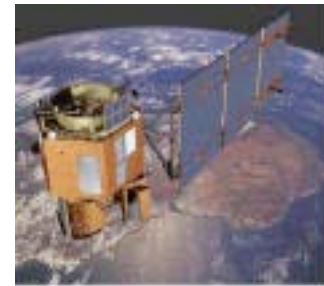
Application Integration

- Declarative models
 - Ease of use, sustainment engineering
- Planner services
 - Customization of planners, process and products
 - Ease of integration



Planning and Scheduling Overview

- Philosophy
 - Planning
 - Scheduling
- Technology
 - Handling Uncertainty
 - Constraints and Optimization
 - Application Integration
- **Activity**



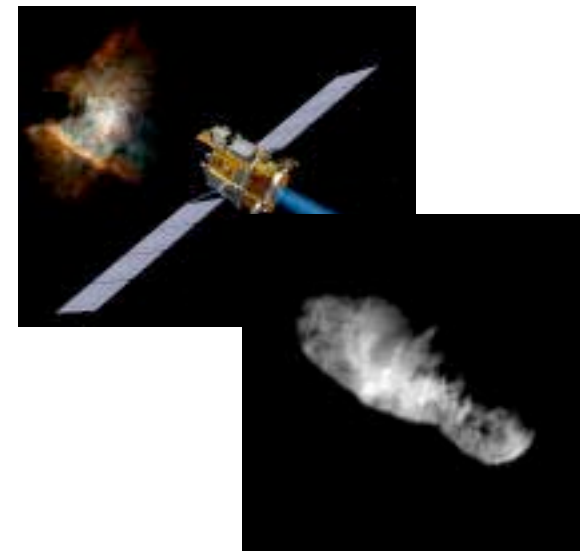
Projects Overview

- Legacy
 - IS-Directed projects
- ESMD
 - IS NRA
 - CDS
 - Extramural
- AIST
- Special Projects

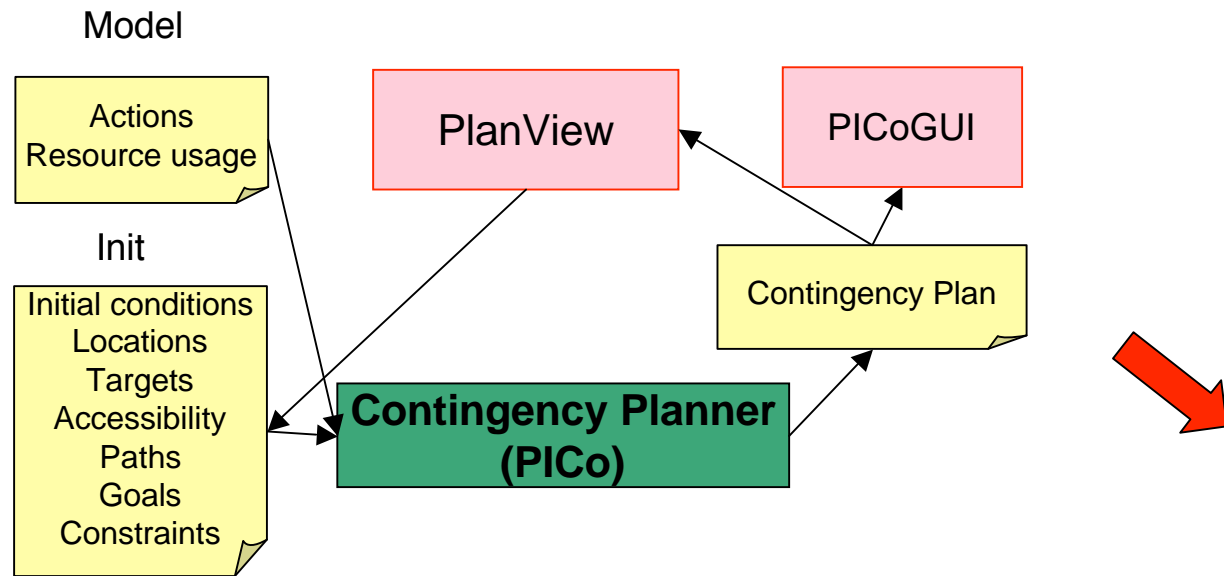


Legacy Projects

- Constraint-based Planning
- Contingency Planning
- Automated Flight Planning



Contingency Planning



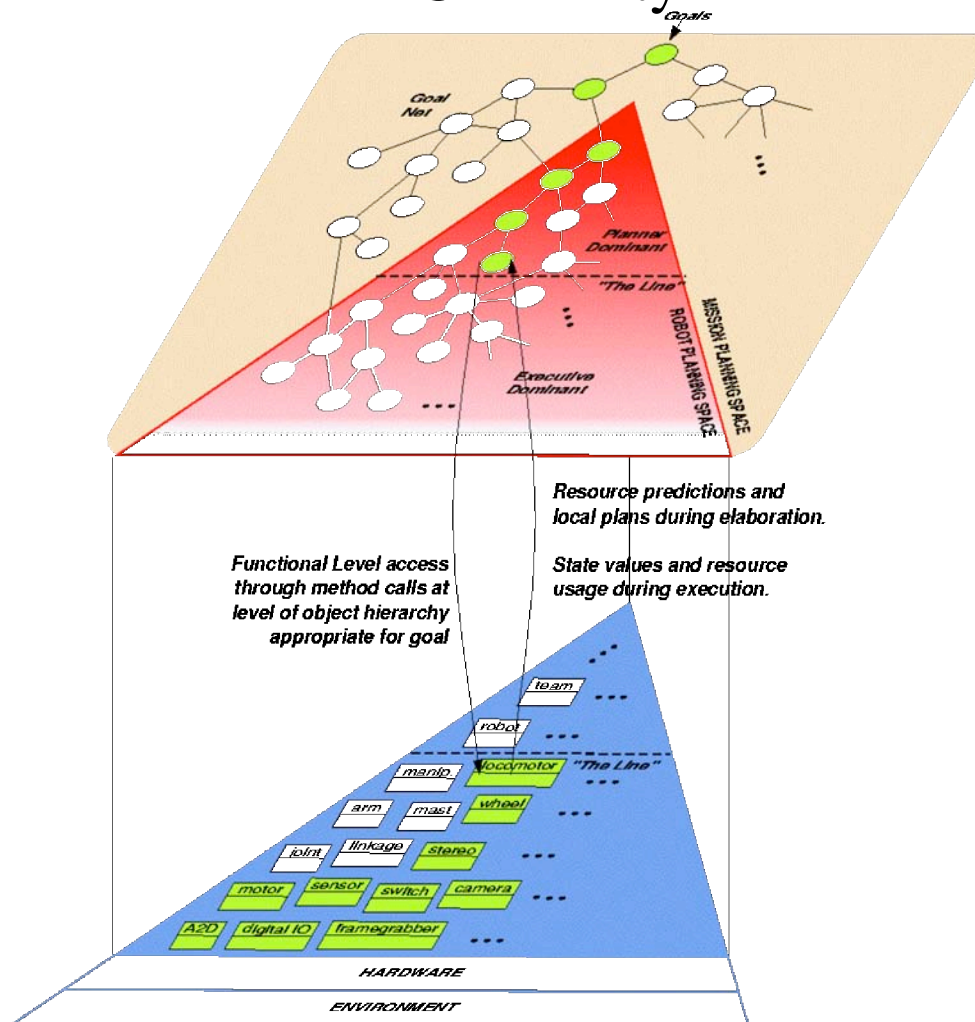
Exploration Systems

- IS NRA Projects
 - Decision-Theoretic Planning
 - Mixed-Initiative Planning
 - (DES/JPL)
- CDS
 - Rover Replanning Demonstration
- Extramural Projects
 - Autonomy V&V



Autonomy V&V

CLARAty



THE DECISION LAYER:

Add functionality to support exploration and construction tasks

Generalize support for planners and executives

Add support for software synthesis approaches

THE INTERFACE:

Synthesize controllers across Decision Layer and Functional Layer

Automated V&V of Decision Layer components synthesized from Functional Layer components

THE FUNCTIONAL LAYER:

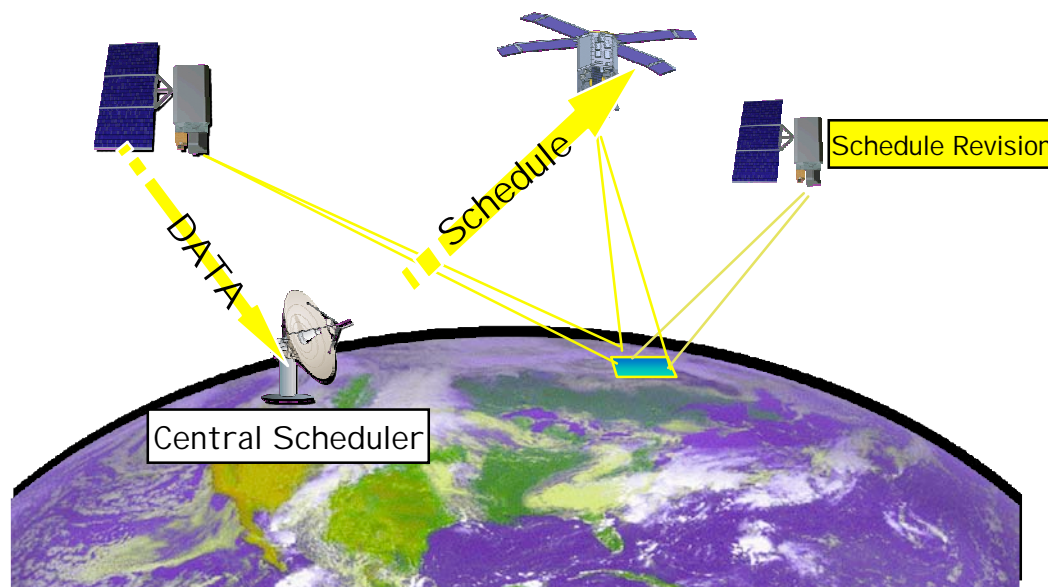
Synthesize functional layer components

Add support for software synthesis approaches

Hierarchical V&V of functional components

AIST

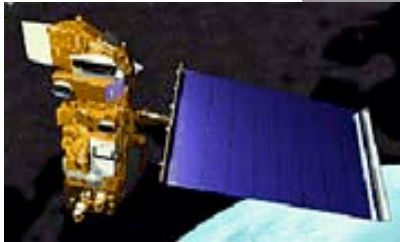
- Eco-Forecasting
- Satellite Constellation Scheduling



Eco-Forecasting

Climate Data

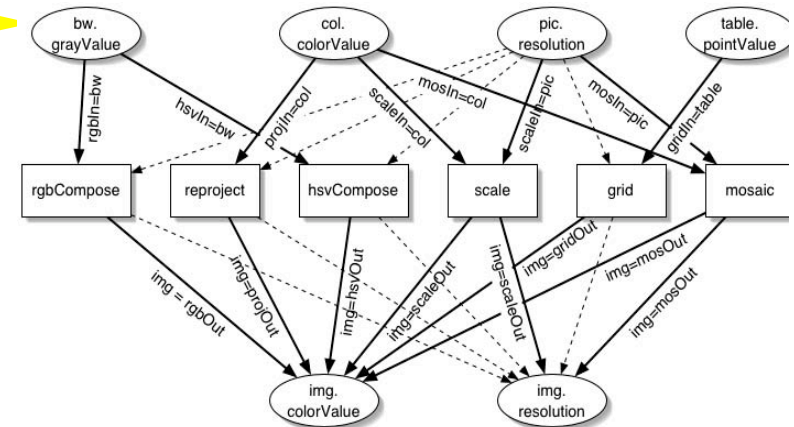
Satellite Data



Ancillary Data



DATA

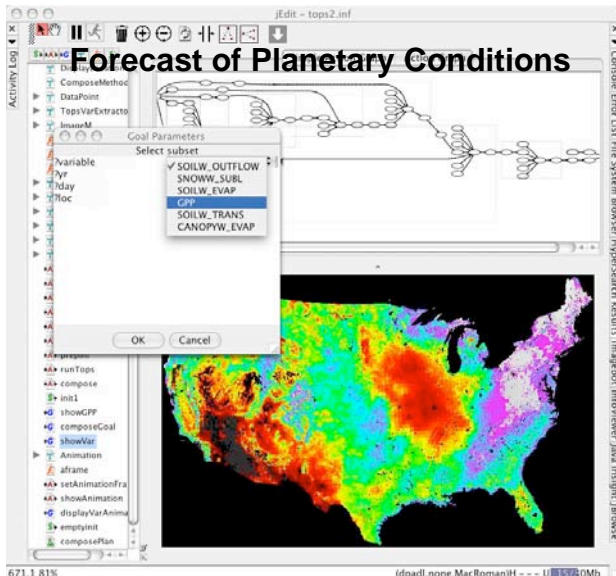


Planning

Information



**User
Community**



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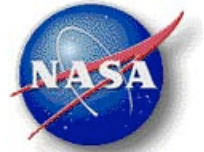
ASR Group Introductions



Special Projects

- Game-Theoretic Scheduling (DDF)
- Intelligent Mission Management for UAVs (AuRA/Vehicle Systems)
- Flexible Scheduling (JDF,Mus,DJR)
- Scheduling with Preferences (RAM,PHM,LK)





Partnerships

- Inside Ames
 - ASE, DASH, CAS
 - Code S (SOFIA, Remote Sensing)
 - Code R (UAVs)
- Outside Ames
 - JPL
 - GSFC
- Outside NASA
 - U. Montana, UCSC, UW, BGU, FDHU
 - Adventium, Sandia, SRI, Raytheon



Oh yeah, we publish too.



- J. Frank and A. Jonsson. Constraint-Based Attribute and Interval Planning. J. Constraints 8(4) 2003
- J. Frank. Bounding the Resource Availability of Partially Ordered Events with Constant Resource Impact. 10th Intl. Conference on Constraint Programming, 2004
- A. Bachmann et al. PLASMA: A Constraint-Based Planning Architecture. (Demonstration) 10th Intl. Conference on Constraint Programming 2004.
- P. Morris et al. Strategies for Global Optimization of Temporal Preferences. 10th Intl. Conference on Constraint Programming, 2004.
- N. Meuleau et al. Optimal Limited Contingency Planning. Proceedings of the 19th Conference on Uncertainty in AI, 2003.
- D. Smith. Choosing Objectives in Oversubscription Planning. 14th International Conference on Automated Planning and Scheduling, 2004.
- Mitchell Ai-Chang et al. MAPGEN: Mixed-Initiative Planning and Scheduling for the Mars Exploration Rover Mission, IEEE Intelligent Systems, 2004.
- K. Golden et al. Automating the Processing of Earth Observation Data. 7th International Symposium on AI, Robotics and Automation for Space, 2003.
- D. Sullivan et al. Intelligent Mission Management for Uninhabited Air Vehicles. Proceedings of the 4th SPIE Symposium on Remote Sensing for Atmosphere, Ocean, Environment and Space, 2004.
- N. Meuleau et al.

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ASR Group Introductions

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